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of

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for a

METHOD AND DEVICE FOR DETECTING TOUCH PAD INPUT

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METHOD AND DEVICE FOR DETECTING TOUCH PAD INPUT

Cross Reference to Related Applications

Reference is made to pending application (Attorney Docket No. 944-003.101) entitled METHOD AND SYSTEM FOR PREVENTING UNINTENDED TOUCH PAD INPUT DUE TO ACCIDENTAL TOUCHING, assigned to the assignee of the present invention and filed on even date herewith.

Field of the Invention

The present invention relates generally to a touch sensitive device in an electronic device or a wireless telecommunication terminal.

Background of the Invention

A touch pad is usually defined as a touch-sensitive user interface area in an electronic device, which allows a user to input information or a command to the device by pressing the touch sensitive area. The touch pad can be used as a keypad having a designated functionality. For example, a touch pad can be used as an on/off switch and the user can turn the electronic device on or off by pressing the touch sensitive area. The touch pad can have several selectable functions. For example, the touch pad can be used as a keyboard having a plurality of soft-keys of different functions to allow the user to enter or select one function at a time.

In some touch pads, it is required to press the pad surface in order to deform it. In such a touch pad, several layers of material, separated by thin spacers, are used to form a grid of vertical and horizontal rows of electrodes. An electrical current is maintained in the grid of electrodes. When a user presses the pad, the layers are caused to make contact with each other at the pressing point, thereby interrupting the current in the electrode grid. A detection circuit is used to detect the interruption in the current and determine the location of the pressing point on the pad. In other touch pads, mere touching of the pad surface by a finger is sufficient. This latter type of touch pad can be of a resistive-type or capacitive-type. On a resistive-type touch pad, a thin, electrically conductive and resistive layer is coated on the surface of the touch pad area. On a capacitive-type touch

pad, a coated layer forming a matrix of pixel-like capacitors is provided on the touch sensitive area. When a finger touches the surface, it changes the electrical characteristics of the coated layer. By measuring the resistance or capacitance values at a number of surface points corresponding to the pressing point, the location of the pressing point can be determined. On an inductive-type touch pad, inductive elements are distributed over the touch pad area. A stylus made of an inductive material is used to change the signals transmitted through the inductive elements for the detection of the presence of the stylus. In some touch pads, if the user moves the touching object around the touch sensitive area and a series of pressing points are registered, the movement of the touching object can also be calculated.

When the touch pad is also used as an information display or an image display, the electrodes positioned on top of a touch pad may affect the optical transparency of display and/or distort the displayed text or image. Furthermore, some touch pads can be damaged by having dirt or scratches on the touch pad surface. In recent years, surface wave technology is also used in touch pad applications. In particular, ultrasonic waves propagating on the touch pad surface are used to detect the interruption or absorption of the waves due to touching. While a touch pad using this surface wave technology does not affect the optical quality of the display, it is costly to produce.

It is advantageous and desirable to provide a touch pad, which is cost effective and does not affect its optical quality.

Summary of the Invention

According to the first aspect of the present invention, a method of sensing and detecting the presence of an object at a touch pad device having one or more input functions, wherein the touch pad device has a designated interaction area for allowing a user to use the object to interact with the touch pad device to facilitate the input of touch pad functions, said method comprising the steps of:

providing at least one group of optical sensor components including a first light emitter, a second light emitter and a light receiver in the touch pad device at different locations thereof such that the receiver is capable of receiving a first amount of light emitted by the first light emitter and a second amount of light emitted by the second light

emitter; wherein when the object is present at the touch pad device, causes a change in the first amount of light and the second amount of light;

measuring separately the change in the first amount of light and the change in the second amount of light for providing a first signal and a second signal indicative of the respective changes; and

determining the location of the object in the designated interaction area in relation to the first light emitter and the second light emitter based on the first and second signals.

It is preferable that the first and second emitters are operated in a pulsed mode of a predetermined frequency so that the changes in the first amount of light and second amount of light contain a frequency component so as to distinguish the changes in the first amount of light and second amount of light due to the presence of the object over the changes due to ambient light.

It is further preferable to provide a compensation emitter, which is placed adjacent to the receiver and operated in a pulsed mode of the same frequency, but with a complementary phase regarding the first and second emitters, so as to reduce the effect of the surface condition of the touch pad device on the changes in the first amount of light and second amount of light.

It is also preferable to provide a second group of similar optical sensor components in the touch pad device placed at different locations for further determining the location of the object in the designated interaction area in relation to light emitters in the second group of optical sensor components. The optical sensor components can be placed within the designated interaction area or outside the designated interaction area.

According to the second aspect of the present invention, a touch pad device to be used in conjunction with a measurement device, the touch pad device having a designated interaction area for sensing and detecting the presence of an object at the designated interaction area, said touch pad device comprising:

a light receiver provided in or near the designated interaction area, and

a first light emitter and a second light emitter provided respectively at a first location and a second different location in the designated interaction such that the receiver is capable of receiving a first amount of light emitted by the first light emitter and a second amount of light emitted by the second light emitter, wherein when the object

is present at the touch pad device, causes a change in the first amount of light and the second amount of light, the change in the first amount of light and the change in the second amount of light being separately measured by the measurement device for determining the location of the object in the designated interaction area in relation to the first light emitter and the second light emitter based on the first and second signals.

It is preferable that the first and second emitters are operated in a pulsed mode of a predetermined frequency so that the changes in the first amount of light and second amount of light contain a frequency component so as to distinguish the changes in the first amount of light and second amount of light due to the presence of the object over the changes due to ambient light.

It is further preferable to provide a compensation emitter, which is placed adjacent to the receiver and operated in a pulsed mode of the same frequency, but with a complementary phase regarding the first and second emitter, so as to reduce the effect of the surface condition of the touch pad device on the changes in the first amount of light and second amount of light.

It is also preferable that the touch pad device further comprises a second group of similar optical sensor components placed in or near the designated interaction area at different locations from the locations of the first and second light emitters and the receiver for further determining the location of the object in the designated interaction area in relation to light emitters in the second group of optical sensor components. The optical sensor components can be placed inside the designated interaction area or outside the designated interaction area.

According to the third aspect of the present invention, a system for sensing and detecting the presence of an object at a touch pad device, wherein the touch pad device has a designated interaction area for allowing a user to use the object to interact with the touch pad device, said system comprising:

at least one group of optical sensor components including a first light emitter, a second light emitter and a light receiver in the touch pad device at different locations thereof such that the receiver is capable of receiving a first amount of light emitted by the first light emitter and a second amount of light emitted by the second light emitter,

wherein the first amount of light and the second amount of light are caused to change when the object is present at the touch pad device;

means, operatively connected to the light receiver, for separately measuring the change in the first amount of light and the change in the second amount of light for providing a first signal and a second signal indicative of the respective changes; and

means, responsive to the first signal and second signal, for determining the location of the object in the designated interaction area in relation to the first light emitter and the second light emitter based on the first and second signals.

It is preferable that the first and second emitters are operated in a pulsed mode of a predetermined frequency so that the changes in the first amount of light and second amount of light contain a frequency component so as to distinguish the changes in the first amount of light and second amount of light due to the presence of the object over the changes due to ambient light.

It is further preferable to provide a compensation emitter, which is placed adjacent to the receiver and operated in a pulsed mode of the same frequency, but with a complementary phase regarding the first and second emitter, so as to reduce the effect of the surface condition of the touch pad device on the changes in the first amount of light and second amount of light.

It is also preferable to provide a second group of similar optical sensor components in the touch pad device placed at different locations for further determining the location of the object in the designated interaction area in relation to light emitters in the second group of optical sensor components.

The present invention will become apparent upon reading Figures 1 to 15.

<u>Brief Description of the Drawings</u>

Figure 1 is a diagrammatic representation showing the general principle of the present invention, where a group of two light emitters and a light receiver is used to detect the presence of a nearby object.

Figure 2A is a diagrammatic representation showing a touch pad device having a group of optical sensor components placed near the top side of the touch pad area.

Figure 2B is a diagrammatic representation showing a touch pad device having a group of optical sensor components placed near the bottom side of the touch pad area.

Figure 2C is a diagrammatic representation showing a touch pad device having a group of optical sensor components placed near the left side of the touch pad area.

Figure 2D is a diagrammatic representation showing a touch pad device having a group of optical sensor components placed near the right side of the touch pad area.

Figure 3A is a diagrammatic representation showing the measurement of the change in the receiver output attributable to one light emitter in a group of optical sensor components.

Figure 3B is a diagrammatic representation showing the measurement of the change in the receiver output attributable to the other light emitter in a group of optical sensor components.

Figure 4A is a diagrammatic representation showing a touch pad device having two groups of optical sensor components separately placed near the top side and the bottom side of the touch pad area.

Figure 4B is a diagrammatic representation showing a touch pad device having two groups of optical sensor components separately placed near the left side and right side of the touch pad area.

Figure 5A is a diagrammatic representation showing a touch pad device of Figure 4A, wherein one emitter and the receiver near the top side are used for measurement.

Figure 5B is a diagrammatic representation showing a touch pad device of Figure 4A, wherein another emitter and the receiver near the top side are used for measurement.

Figure 5C is a diagrammatic representation showing a touch pad device of Figure 4A, wherein one emitter and the receiver near the bottom side are used for measurement.

Figure 5D is a diagrammatic representation showing a touch pad device of Figure 4A, wherein another emitter and the receiver near the bottom side are used for measurement.

Figure 5E is a diagrammatic representation showing the touch pad device of Figure 4A, wherein one emitter near the top side and the receiver near the bottom side are used for measurement.

Figure 5F is a diagrammatic representation showing the touch pad device of Figure 4A, wherein another emitter near the top side and the receiver near the bottom side are used for measurement.

Figure 5G is a diagrammatic representation showing the touch pad device of Figure 4A, wherein one emitter and the receiver near the top side, and one emitter near the bottom side are used for measurement.

Figure 5H is a diagrammatic representation showing the touch pad device of Figure 4A, wherein another emitter and the receiver near the top side, and another emitter near the bottom side are used for measurement.

Figure 6A is a diagrammatic representation showing a touch pad device having four groups of optical sensor components separately placed near four sides of the touch pad area.

Figure 6B is a diagrammatic representation showing a touch pad device having four emitters separately placed near the four corners, and four receivers separately placed near the four edges of the touch pad area.

Figure 7 is a diagrammatic representation showing a touch pad device and two groups of optical sensor components mounted on a printed wire board.

Figure 8A is a cross-sectional side view showing a touch pad device having an LCD and a light guide on top of the LCD for touching.

Figure 8B is a cross-sectional side view showing a touch pad device having an LCD and a thin cover on top of the LCD for touching.

Figure 8C is a cross-sectional side view showing a touch pad device having an LCD and a curved cover on top of the LCD for touching.

Figure 8D is a diagrammatic representation showing light transmission within the light guide in the touch pad device of Figure 8A.

Figure 9A is a diagrammatic representation showing a touch pad device having one group of optical sensor components placed within the touch pad area.

Figure 9B is a diagrammatic representation showing another touch pad device having one group of optical sensor components placed within the touch pad area.

Figure 9C is a diagrammatic representation showing a touch pad device having two groups of optical sensor components placed within the touch pad area.

Figure 9D is a diagrammatic representation showing another touch pad device having two groups of optical sensor components placed within the touch pad area.

Figure 9E is a diagrammatic representation showing a touch pad device having four groups of optical sensor components placed within the touch pad area.

Figure 9F is a diagrammatic representation showing a touch pad device having four light emitters and four light receivers placed within the touch pad area.

Figure 10A is a diagrammatic representation showing the light output of a light emitter operated in a pulsed mode.

Figure 10B is a diagrammatic representation showing the output signal of a receiver attributable to a light emitter operated in a pulsed mode.

Figure 10C is a diagrammatic representation showing the output signal of a receiver attributable to a light emitter operated in a pulsed mode and ambient light.

Figure 10D is a diagrammatic representation showing the light output of a compensation emitter.

Figure 10E is a diagrammatic representation showing the output signal of a receiver attributable to a light emitter and a compensation emitter operated in a pulsed mode with complementary phases.

Figure 11 is a diagrammatic representation showing the reflection of light emitted from two light emitters and a compensation emitter off a finger to reach a light receiver.

Figure 12A is a diagrammatic representation showing a touch pad device having one group of optical sensor components operated in a pulsed mode including two light emitters, one compensation emitter and one light receiver.

Figure 12B is a diagrammatic representation showing a touch pad device having two groups of optical sensor components operated in a pulsed mode placed near the touch pad area.

Figure 12C is a diagrammatic representation showing a touch pad device having two groups of optical sensor components operated in a pulsed mode placed within the touch pad area.

Figure 13A is a diagrammatic representation showing a touch pad device having four transceivers placing near the four edges of the touch pad area.

Figure 13B is a diagrammatic representation showing a touch pad device having four transceivers placing near the four corners of the touch pad area.

Figure 13C is a diagrammatic representation showing a touch pad device having four transceivers placing inside the four edges of the touch pad area.

Figure 13D is a diagrammatic representation showing a touch pad device having four transceivers placing inside the four corners of the touch pad area.

Figure 14 is a block diagram showing a system for detecting the presence of an object near the touch pad area of a touch pad device, according to the present invention.

Figure 15 is a block diagram showing a mobile phone comprising a touch pad device, according to the present invention.

Detailed Description of the Invention

As shown in Figure 1, two light emitters **10, 20** are positioned on opposite sides of a light receiver **30** in the proximity of a touch pad **5** (see Figures 2A-2D). When a user uses an object such as a pencil **100** or a finger **100'** (Figure 2A) to touch the touch pad **5**, some light **110** emitted from the emitter **10** encounters the surface of the object **100**. Part of the light **110** reflects off the object **100** and is received by the receiver **30**. Likewise, some light **120** emitted from the emitter **20** encounters the surface of the object **100** and then reflects off the object **100** to receiver **30**. The received portions are denoted by reference numerals **112** and **122**. The amount of light received by the receiver **30** can be measured from the output signal **130**. If the receiver **30** is not already saturated by ambient light, the presence of the object **100** near the emitters **10, 20** and the receiver **30** would cause a change in the output signal **130**. When such a change is detected, it is preferred that the change attributable to the reflected light **112** and that attributable to the reflected light **122** are separately measured by turning off the emitter **20** and emitter **10**, respectively. As shown in Figure 3A, the emitter **20** is turned off or disabled while the change in the received light amount **112** is measured. Likewise, the emitter **10** is turned off or disabled while the change in the received light amount **122** is measured, as shown in Figure 3B. In Figures 3A and 3B, the emitter and receiver involved in the measurement are enclosed by a dashed loop. From the changed amounts, it is usually possible to determine whether the object **100** is closer to the emitter **10** or the emitter **20**.

In general, when the object **100** is closer to the emitter **10** than the emitter **20**, the output signal **130** responsive to the change in the received light amount **112** is larger than that in the received light amount **122**. With a series of such measurements, it is possible to track the positions of the object **100** and thus its movement.

Figures 2A-2D illustrate different arrangements of the light emitters **10, 20** and the receiver **30** in a touch pad device **1**. As shown in Figure 2A, the touch pad device **1** has a "touch sensitive" area **5** surrounded by a peripheral area **3**. If the touch pad device **1** is a resistive-type device, for example, the surface of the "touch sensitive" area must be physically touched in order to change the resistance. However, according to the present invention, the presence of the object **100'** is detected by optical sensor components **10, 20** and **30**. It is not necessary for the object **100'** to physically touch or press the area **5** at a touching point. Thus, the area **5** can be considered as a designated interaction area where a user can use the object **100'** to interact with the touch pad device **1** in order to select the input functionality thereof. Furthermore, the phrase "touching the surface", as used hereinafter regarding the touch pad device **1** of the present invention, can be interpreted as "making contact with the surface" or "being adjacent to the surface". Similarly, the location of the "touching point" simply means the selected input location within the touch pad area **5**.

The touch pad device **1** can have a single input functionality or multiple input functionality. For example, the touch pad device **1** can be used as an "enter" key in a keyboard, as shown in Figure 2B, or a toggle ON/OFF switch, as shown in Figure 2D. With one or more cycles of measurement, it is possible to detect the presence of an object intended for selecting the input functionality of the touch pad device **1**. The touch pad device 1, as shown in Figure 2A, can be used to select the "ON" function or "OFF" function, depending on the location of "touching" point on the touch pad area **5**. When the user's finger **100'** touches or approaches the pad area **5**, as shown in Figure 2A, it is usually possible to determine from the changes in the output signal of the receiver **30** that the OFF function is selected.

In Figure 2B, the sensor components **10, 20** and **30** are arranged in the peripheral area **3** near the bottom side of the touch area **5**. Likewise, the sensor components **10, 20** and **30** can be arranged near the top side, left side and right side of the touch pad area **5**,

as shown in Figures 2B, 2C and 2D, respectively. With one group of optical sensor components placed in a row in a certain direction, one or more functions can be selected based on the location of the touching point along that direction in one dimension.

It should be noted that with the arrangement of optical sensor components, as shown in Figures 2A-2D, the location of the touching point where the object is adjacent to the touch pad area **5** can be determined if the reflection from the object surface does not vary significantly from one point to another. However, if the touching object is a pencil, as shown in Figure 1, different parts of the pencil may reflect light differently. In that case, a larger amount of change in the received light in the receiver **30** does not necessarily mean that the touching point is closer to one emitter or another. This means that the location of the touching point may not be accurately obtained. With the touch pad device **1** having a single input functionality, one group of sensor components **10, 20** and **30** is generally sufficient to sense the touching of the touch pad area **5**. However, when the location of the touching point within the touch area **5** is important in determining the selected function, it is preferred that two groups of three optical sensor elements be placed on opposite sides of the touch pad area **5**, as shown in Figures 4A and 4B.

In Figure 4A, emitters **10, 20** and receiver **30** are placed near the top side of the touch pad area **5**. Additionally, emitters **12, 22** and receiver **32** are placed near the bottom side of the touch pad area **5**. As such, the touch pad device **1** can have more than two functions arranged in two dimensions. For example, the user can select the "UP", "DOWN", "RIGHT" or "LEFT" function by touching at or near the respective arrow. Alternatively, the two groups of optical sensor elements can be separately placed near the right and left sides of the touch pad area **5**, as shown in Figure 4B.

With four emitters **10, 12, 20, 22** and two receivers **30, 32**, it is preferred that a series of measurements, each using a different emitter/receiver pair, be carried out to determine the location of the touching point. For example, the measurement result from the emitter **10** and receiver **30** pair (Figure 5A) is compared to the measurement result from the emitter **20** and receiver **30** (Figure 5B) in order to determine the upper horizontal location of the touching point. Additionally, the measurement result from the emitter **12**/receiver **32** pair (Figure 5C) is compared to the measurement result from the emitter

22/receiver **32** pair (Figure 5D) in order to determine the lower horizontal location of the touching point. From these four measurements (Figures 5A-5D), it is possible to calculate the two-dimensional coordinates of the touching point. However, in order to improve the accuracy in location determination, it is preferable to also carry out the following measurements: the emitter **10**/receiver **32** pair (Figure 5E); the emitter **20**/receiver **32** pair (Figure 5F); the emitter **12**/receiver **30** pair (not shown) and the emitter **22**/receiver **30** pair (not shown). The series of eight measurements are summarized in TABLE I, where TX1=emitter **10**, TX2= emitter **20**, TX3=emitter **12**, TX4=emitter **22**, RXU=receiver **30** and RXD=receiver **32**.

	TX1	RXU	TX2	TX3	RXD	TX4	measured direction
1	on	on	off	off	off	off	horizontal, upper
2	off	on	on	off	off	off	horizontal, upper
3	off	off	off	on	on	off	horizontal, lower
4	off	off	off	off	on	on	horizontal, lower
5	off	on	off	on	off	off	diagonal/
6	off	off	on	off	on	off	diagonal/
7	on	off	off	off	on	off	diagonal\
8	off	on	off	off	off	on	diagonal\

TABLE I

As can be seen in TABLE I, only one emitter and one receiver are used, or enabled, for measurement at a time. All the other sensor elements are disabled or not used. The enabling and disabling of the optical sensor components is carried out by a timing control module, as shown in Figure 14. If the turn-on time is one millisecond for each measurement cycle, it will take only eight milliseconds to complete all the measurement cycles. It is understood that one series of eight measurement cycles can be used to determine the-two dimensional coordinates of the touching point with respect to the touch pad area **5**. By repeating the same series, the movement of the approaching object can also be tracked.

Optionally, the output from two emitters can be combined in a single measurement. For example, the measurement result from the emitters **10, 22** and the receiver **30** (Figure 5G) is compared to the measurement result from the emitters **12, 20** and the receiver **30** (Figure 5H). This comparison is used to determine the horizontal location of the touching point. Likewise, the measurement result from the emitters **10, 22** and the receiver **32** is compared to the measurement result from the emitters **12, 20** and the receiver **32** in order to determined the horizontal location.

Four groups of sensor components can be placed on four sides of the touch pad area **5**, as shown in Figure 6a. Similar to the measurements using the emitters **10, 12, 20, 22** and receivers **30, 32**, as shown in Figures 5A-5E and summarized in TABLE I, another series of eight measurements can be carried out with emitters **14, 16, 24, 26** and receivers **34, 36**. At any one time, only one emitter and one receiver are turned on for measurement. If it takes 1 ms to make one measurement cycle using one emitter/receiver combination, similar to the cycles shown in TABLE I, it requires 16 ms to make all such cycles.

Alternatively, all the emitters **10**, **12**, **14**, **16**, **20**, **22**, **24** and **26** are operated in a pulsed mode of a predetermined frequency. However, the emitters **10**, **20**, **12** and **22** are operated in a phase complementary of the phase of the emitters **14**, **24**, **16** and **26**. As such, a measurement of the horizontal position can be made simultaneously with a measurement of the vertical position in order to reduce the measurement time.

It is also possible that the operating wavelength of the sensor components **14, 16, 24, 26, 34** and **36** is different from the operating wavelength of the sensor components **10, 12, 20, 22, 30** and **32**. In that case, two measurements of different wavelengths can be made simultaneously. For example, the measurement taken with the emitter **10** and the receiver **30** can be carried out simultaneously with the measurement taken with the emitter **14** and the receiver **34**. With two wavelengths, the measurement time can be reduced in half.

Alternatively, two emitters at each corner can be replaced by a bi-wavelength emitter, as shown in Figure 6b. For example, the emitters **10** and **14** can be replaced by a bi-wavelength emitter **11**. Likewise, bi-wavelength emitters **21, 23** and **13** are used to replace all other single-wavelength emitters.

In a mobile device or other electronic device, the touch pad area **5** can be a display panel such as a liquid crystal display (LCD) **92** mounted on a printed circuit board (PCB) or a printed wire board (PWB) **90**. As shown in Figure 7, the optical sensor components **10, 12, 20, 22, 30** and **32** are mounted in the peripheral area surrounding the LCD **92.** Preferably, the touch pad device **1** also includes a cover plate to provide a touch surface. As shown in Figure 8A, a cover plate **60** is placed on top of the LCD **92** and the optical sensor components (only emitters **10** and **12** are shown). The cover plate **60** is designed as a light guide such that light emitted from the emitter **10** can reach the receiver **30** (see Figure 8D) and light emitted from the emitter **12** can be reach the receiver **32** (not shown) by way of total internal reflection, for example, when the touch pad device **1** is touched by or adjacent to the object **100**. In Figure 8D, the light ray **201** that reaches the receiver **30** is by way of total internal reflection. The light rays **202, 204** reach the receiver **30** by way of partial reflection. When a user's finger **100'** (Figure 2) approaches the cover plate **60**, the light rays **203, 205** could encounter the approaching finger and partially reflect off the finger toward the receiver **30**. Reflection causes the increase in the received light amount by the receiver **30**. However, when the finger makes contact with the upper surface **62** of the cover plate **60**, the total internal reflection at the touching point is destroyed, decreasing the received light amount by the receiver **30**. Accordingly, both the increase and the decrease of the received light amount by the receiver **30** indicate that touch pad device **1** is "touched". In order to increase the received light amount by the receiver **30** when the surface **62** is not touched, it is possible to introduce some surface defects **67** on the lower surface **64** of the cover plate **60** at the receiver **30**, as shown in Figure 8D. With the cover plate **70**, as shown in Figure 8B, there is very little light from the emitters that reaches the receiver. The approaching and touching of the user's finger is detected by the reflection off the finger. With the cover plate **80** as shown in Figure 8C, the amount of light emitted by the emitters **10, 20** reaching the receiver could be more than that as shown in Figure 8B. However, the approaching and touching of the user's finger **100'** is mainly detected by the reflection off the finger.

In the embodiments, as illustrated in Figures 2A through 8C, all of the optical sensor components are placed outside the touch pad area **5**. The touch pad area **5** can be used as a display to provide messages to the user or to indicate the functionality of the

touch pad device **1**. However, the optical sensor components can also be placed inside the touch pad area **5**, as shown in Figures 9A-9F. In Figures 9A and 9B, one group of optical sensor components, including two emitters **10, 20** and one receiver **30,** is used to detect the location of the touching object and track the movement of thereof in one dimension. The measurements to be carried out using these emitters and receiver are similar to those illustrated in Figures 2A-3B. In Figures 9C and 9D, two groups of similar optical sensor components are placed inside the touch pad area **5**. The arrangement of sensor components and the measurements using the components are similar to those illustrated in Figure 4A-5H. The arrangement of sensor components in Figure 9E is similar to that illustrated in Figure 6A. The arrangement of sensor components in Figure 9F is similar to that illustrated in Figure 6B.

The emitters **10, 11, 12, 13, 14, 16, 20, 21, 22, 23, 24** and **26**, as described herein, can be operated in a continuous mode in that the output of the emitters does not contain a high frequency component, similar to the output of an incandescent lamp. Accordingly, the output signal **130** (Figure 1) of the receiver **30** is also constant or slow-varying. When the emitters are operated in a continuous mode, the output signal of the receiver can be significantly affected by ambient light. This means that the output signal of the receiver may vary from one location to another, regardless of whether the touching object is present at the touch pad device. When the output variation due to ambient light is significant, the detection and sensing of the presence of the touching object becomes difficult, if not impossible. Thus, it is preferable that these emitters be operated in a pulsed mode such that the emitters are turned on and off at regular intervals at a selected frequency. The output intensity $\mathbf{I_E}$ of a pulsed emitter is shown in Figure 10A. Accordingly, the output $\mathbf{I_R}$ of the receiver attributable to the output intensity $\mathbf{I_E}$ of the pulsed emitter is a series of pulses, as shown in Figure 10B, when the receiver receives light from the pulsed emitter, regardless of whether the touching object is present at the touching pad device. The receiver and the emitter are in-phase with each other. Usually, as ambient light varies much slower than the frequency of the pulsed frequency, the variation in the output signal of the receiver due to the variation in ambient light is most likely a shift in the base line of the output signal, as shown in Figure 10C. The output variation due to ambient light can be easily removed using a high-pass filter, for example.

Therefore, the variation in the pulsed output signal of the receiver is mainly the result of the reflection or absorption of the approaching object over the touch pad device.

It should be noted that the output signal of the receiver **30** attributable to a pulsed emitter **10** arranged in a touch pad device, such as that illustrated in Figure 8D, can change if the upper surface **62** of the cover plate **60** is wet or dirty. Such a change could complicate the detection and sensing of the touching object. Thus, it is also preferable to place a compensation emitter **40** adjacent to the receiver **30**, as shown in Figure 11. The phase of the compensation emitter **40**, as shown in Figure 10D, is complementary to the phase of the emitters **10, 20**. In Figure 10D, $\mathbf{I_C}$ denotes the output intensity of the compensation emitter **40**. The compensation emitter **40** is controlled such that when the touching object is not present, the output signal $\mathbf{I_E}$ of the receiver **30** attributable to the emitters **10, 20** is substantially equal to that attributable to the compensation emitter **40**. With such a compensation emitter, the output signal of the receiver **30** does not contain a high frequency component, as shown in Figure 10E, when the touching object is not present. Thus, after being filtered by a high-pass filter, the output signal of the receiver **30** is substantially zero. With such a compensation emitter, the output signal of the receiver **30** is substantially unaffected by the surface condition of the cover plate **60**. The use of a compensation emitter has been disclosed in U.S. Patent No. 5,666,037 entitled "Arrangement for measuring or detecting a change in a retro-reflective element" to Gerd Reime, and in EP 0 706 648 B1 of the same title to the same inventor.

<u>Best Mode</u>

In order to use the above-mentioned phase compensation technique, it is preferred that adjacent to each of the receivers **30, 32, 34, 36**, as shown in Figures 1-7, 8D-9E, a compensation emitter is placed so as to balance out the output of the corresponding emitters (in a pulsed mode). The placement of the compensation emitter is similar to that shown in Figure 11. An exemplary arrangement of the compensation emitter is shown in Figures 12A-12C. As shown, a compensation emitter **40** is placed adjacent to the receiver **30**, and a compensation emitter **42** is placed adjacent to the receiver **32**. In measurements, the compensation emitter adjacent to the corresponding receiver is turned on or off together with that receiver. For example, in the measurement illustrated in

Figure 5E, the compensation emitter adjacent to the receiver **32** is turned on while the compensation emitter adjacent to the receiver **30** is turned off.

Preferably, the light emitters 10, 12, 14, 16, 20, 22, 24 and 26 are light-emitting diodes (LEDs) operated in an infrared (IR) or far-IR frequency range.

<u>Alternative Embodiments</u>

The optical sensor components, as shown in Figures 1-12B, are dedicated components in that an emitter cannot be used as a receiver, and a receiver cannot be used as an emitter. However, it is possible to use optical transceivers in a touch pad device for detecting the presence of a touching object. As shown in Figures 13A-13D, four transceivers A, B, C and D are arranged at the four edges or corners of the touch pad area **5**. Each of the transceivers A, B, C and D can be selectively used either as an emitter or a receiver, but not both. The selected function of the transceiver is denoted by a letter in the accompanying parenthesis: (t)=regular emitter or transmitter, (c)=compensation emitter, and (r)=receiver. With the arrangements as shown in Figures 13A and 13C, a series of measurements is carried out to determine the location of a touching point as follows:

I. A(t), B(t), C(r), D(c)
II. A(t), B(t), C(c), D(r)
III A(r), B(c), C(t), D(t)
IV A(c), B(r), C(t), D(t)

As such, the combination of (I+II) yields a first horizontal position; the combination of (III+IV) yields a second horizontal position; (I+II)-((III+IV) yields the vertical position; and (I+II)+(III+IV) yields the horizontal position. For a sufficient large touch pad area, it is desirable to further include the following measurements:

V. A(t), B(r), C(c), D(t)
VI. A(t), B(c), C(r), D(t)
VII. A(r), B(t), C(t), D(c)

VIII. A(c), B(t), C(t), D(r)

As such, the combination of (V+VI) yields a first vertical position; (VII+VIII) yields a second vertical position; and (V+VI)+(VII+VIII) yields the vertical position.

The measurements regarding the arrangements, as shown in Figures 13B and 13D, are similar.

Figure 14 is a block diagram showing the basic components **400** in a system for detecting the presence of the touching object **100** and determining the location of the touching point on the touch pad area **5**, according to the present invention. A microprocessor or ASIC **460** is connected to the components **400** to control the measurement on the touch pad device and make use of the measurement results therefrom. As shown, the touch pad device includes a touch pad area **5** with two groups of sensor components separately placed at the top side and the bottom side of the touch pad area **5**, similar to Figure 4A. The emitters **10, 12, 20, 22** are connected to an enabling module **420,** which selectively enables or disables the emitters for measurements. The output signal **130** from the receiver **30** and the output signal **132** from the receiver **32** are conveyed to a signal-processing module **450**. The enabling module **420** and the signal-processing module **450** are under the control of a timing control module **430**. For example, in order to make the measurement cycle 5 as shown in TABLE I or Figure 5E, the timing control module sends out a control signal **432** to the enabling module **420** for turning off or disabling the emitters **12, 20, 22** and enabling the emitter **10**. At the same time, the timing control module **430** sends out a control signal **434** to the signal processing module **450** such that only the output signal **132** from the receiver **32** is used. Based on the output signal **132,** the signal processing module **450** sends measurement information **452** to the microprocessor **460**. After receiving the measurement information **452,** the microprocessor **460** sends out a command signal **462** to the timing control **430** for starting the measurement of the next cycle. After all eight measurement cycles are completed, the microprocessor **460** determines the location of the touching point. If the emitters **10, 12, 20** and **22** are operated in a pulsed mode of a predetermined frequency, then the signal-processing module **450** also comprises a filtering means to allow mainly

the frequency component of the predetermined frequency in the output signal **130** and **132** to be measured.

Figure 15 shows a portable electronic device, such as a mobile phone **500** that has a touch pad device of the present invention. As shown, the mobile phone **500** includes the microprocessor **460** and the basic components **400,** as shown in Figure 14. In addition, the mobile phone **500** comprises an antenna **504** connected to an RF module **506** for receiving and transmitting RF signals; a battery **508**, a microphone **512**, a speaker **514** and a keyboard **516**. Also, the mobile phone **500** may have a SIM card reader **508** and other electronic devices, such as display 518. The additional components shown in Figure 15 are known in the art and not part of the present invention. Figure 15 is used to illustrate how a touch pad device can be used on an electronic device such as a mobile phone.

The touch pad device **1**, according to the present invention, has many applications. The touch pad device **1** can be used as a key in a keyboard, as illustrated in Figure 2B; a switch with alternate functions, as illustrated in Figure 2D; and a control switch or device with two or more functions as illustrated in Figures 2A and 2C. The touch pad device **1**, as illustrated in Figure 4A, can be used as a micro-mouse or a pointing device, for example. In order to move an object or a cursor to a desired location on a screen, the user can touch the touch pad area **5** at the designated locations to move the cursor up, down, left or right. It should be noted that because the touch pad device, according to the present invention, can be used to track the movement of the touching object, it can be used to input information using the movement. A touch pad device with only one group of optical sensor components (one receiver and two emitters, with or without a compensation emitter) can detect the movement in one dimension. Such a touch pad device can be used as a volume control switch, for example, and the up/down motion or left/right motion of the touching object can be used to increase or decrease the volume of sound. The same device can be used as a light-dimming switch to allow a user to brighten or dim a light, or a zoom control switch to enlarge or reduce a displayed image on a screen. A touch pad device with two or more groups of optical sensor components can be used to track the movement of the touching device in two dimensions. Such a touch pad device can be used as a micro-mouse where the cursor can be moved in any

direction on the screen following the movement of the touching object. The two-dimensional movement of the touching object can be linear, circular or irregular. Thus, a touch pad device with two or more groups of optical sensor components can be used as a virtual rotation knob, a virtual writing pad or a virtual drawing board.

Instead of being rectangular, the touch pad area can be round, elliptical, polygonal or of a irregular shape.

It should be noted that the transmission and reflection of light, as depicted in the drawings, is for illustrative purposes only. For example, the light rays shown in Figure 11 seem to obey specular reflection. However, a finger has a diffuse surface and light rays can penetrate into the skin. Thus, how light rays interact with the finger is a complex matter.

The present invention provides a method and device for detecting and sensing the presence of a touching object and the movement thereof in or near a touch pad area. The touch pad device 1, as depicted in Figure 2A-13D, is used to provide a time-dependent signal based on a series of measurements. The scope of the present invention includes any applications and products that use the disclosed method and/or device using that time dependent signal. The time duration of the signal, the number of cycles in the series of measurements, and the time duration of each cycle, depend on the applications and products. Furthermore, the output intensity, wavelength and other optical characteristics of the light emitters, the sensitivity and the optical response of the light receivers, and the optomechanical arrangement of these optical sensor components in a touch pad device, according to the present invention, may vary from one application to another.

In the embodiments, as depicted in Figures 4A and 4B, it is preferred that the light emitters **10, 20, 12** and **22** can be operated in a pulsed mode of the same frequency and the same phase. Alternatively, the light emitters **10** and **20** are operated in a first phase and the light emitters **12** and **22** are operated in a second phase complementary of the first phase so that the measurement of cycle 1 (TABLE I) can be made simultaneously with the measurement of cycle 3 or cycle 4, for example. Likewise, the measurement of cycle 5 can be made simultaneously with the measurement of cycle 6. Thus, the measurement time for the entire 8 cycles can be reduced in half.

It is preferred the optical sensor components are solid state devices such as light-emitting diodes, optoelectronic sensors and transceivers operated at IR or far-IR frequencies. However, optical sensor components operated at other frequencies can also be used.

Thus, although the invention has been described with respect to a preferred embodiment thereof, it will be understood by those skilled in the art that the foregoing and various other changes, omissions and deviations in the form and detail thereof may be made without departing from the spirit and scope of this invention.